

Appl. No. : 10/802,593
Filed : March 17, 2004

AMENDMENTS TO THE CLAIMS

This listing of claims will replace all prior versions and listings of claims in the application. Applicant has canceled Claims 20-25 without prejudice. Applicant has amended Claims 1-3, 7, 8, 11-13 and 16-19, and added new Claims 26-34 as follows:

1. (Currently Amended) A photodiode, comprising:
 - a substrate;
 - a first conduction type buffer layer formed over ~~on a first surface of~~ the substrate;
 - an amplifying layer formed over ~~on~~ the first conduction type buffer layer;
 - a second conduction type field controlling layer formed over ~~on~~ the amplifying layer, the second conduction type field controlling layer comprising a central portion and a peripheral portion positioned on a side of the central portion in a horizontal direction thereof, the central portion having a charge density higher than that of the peripheral portion;
 - ~~a second conduction type ion injection layer formed within the field controlling layer;~~
 - a second conduction type light-absorbing layer formed over ~~on~~ the field controlling layer;
 - a second conduction type buffer layer formed over ~~on~~ the light-absorbing layer;
 - and
 - a first electrode and a second electrode formed to electrically contact the first conduction type buffer layer and the second conduction type buffer layer, respectively.
2. (Currently Amended) The photodiode according to claim 1, further comprising a second conduction type ohmic contact layer formed between the second ~~conduction~~ conduction type buffer layer and the second electrode.
3. (Currently Amended) The photodiode according to claim 2, further comprising a passivation layer covering a surface of the second conduction type ohmic contact layer and a surface of the first conduction type buffer layer, ~~while allowing the first electrode to electrically contact the first conduction type buffer layer and the second electrode to electrically contact the second conduction type ohmic contact layer.~~

Appl. No. : 10/802,593
Filed : March 17, 2004

4. (Previously Presented) The photodiode according to claim 1, further comprising an anti-reflection layer formed on a surface of the substrate which faces away from the first conduction type buffer layer.

5. (Previously Presented) The photodiode according to claim 1, wherein each of the first conduction type buffer layer, the second conduction type field controlling layer, and the second conduction type buffer layer comprises an InP semiconductor layer, and wherein the second conduction type light-absorbing layer comprises an InGaAs semiconductor layer.

6. (Previously Presented) The photodiode according to claim 1, wherein the first conduction type buffer layer comprises an InP semiconductor layer and an InAlAs semiconductor layer.

7. (Currently Amended) ~~The photodiode according to claim 1,~~ A photodiode, comprising:

a substrate;

a first conduction type buffer layer formed over a first surface of the substrate;

an amplifying layer formed over the first conduction type buffer layer;

a second conduction type field controlling layer formed over the amplifying layer;

a second conduction type ion injection layer formed within the field controlling

layer;

a second conduction type light-absorbing layer formed over the field controlling

layer;

a second conduction type buffer layer formed over the light-absorbing layer; and

a first electrode and a second electrode formed to electrically contact the first conduction type buffer layer and the second conduction type buffer layer, respectively,

wherein a total charge density of the second conduction type ion injection layer and the second conduction type field controlling layer is $3 \times 10^{12}/\text{cm}^2 \pm 20\%$, and

wherein a charge density of a region of the second conduction type ~~field~~ field controlling layer where the second conduction type ion injection layer is not formed is $2 \times 10^{12}/\text{cm}^2 \pm 20\%$.

Appl. No. : 10/802,593
Filed : March 17, 2004

8. (Currently Amended) The photodiode according to claim 1, wherein the amplifying layer comprises at least one of an the InAlAs semiconductor layer and an InAlGaAs semiconductor layer.

9. (Original) The photodiode according to claim 1, wherein the second electrode is formed in a ring structure so as to project a plurality of optical signals toward the second electrode.

10. (Previously Presented) The photodiode according to claim 1, wherein the substrate comprises one of a first conduction type InP semiconductor layer and a semi-insulation InP semiconductor layer.

11. (Withdrawn - Currently Amended) A method for fabricating the a photodiode of Claim 1, comprising:

providing ~~preparing~~ a substrate;

providing a first conduction type buffer layer over the substrate;

providing an amplifying layer over the first conduction type buffer layer; ~~having a superlattice structure~~;

providing a second conduction type field controlling layer, ~~and a surface protection layer on the substrate~~ over the amplifying layer, the second conduction type field controlling layer comprising a central portion and a peripheral portion positioned on a side of the central portion in a horizontal direction thereof;

injecting ions into the central portion of the field controlling layer ~~so as to form a second conduction type ion injection layer~~;

providing ~~removing the surface protection layer and serially forming~~ a second conduction type light-absorbing layer over the second conduction type field controlling layer;

providing a second conduction type field buffer layer over the second conduction type light-absorbing layer; ~~and a second conduction type ohmic contact layer on the field controlling layer~~;

~~selectively removing the second conduction type ohmic contact layer, the second conduction type field buffer layer, the second conduction type light-absorbing layer, the second conduction type field controlling layer, and the amplifying layer having the~~

~~superlattice structure, based on the ion injection layer, so as to expose a surface of the first conduction type buffer layer, thereby forming a mesa structure;~~

~~forming a passivation layer on an entire surface of the substrate, so as to form a plurality of contact holes on the ohmic contact layer and the first conduction type buffer layer; and~~

~~providing forming a first electrode and a second electrode electrically contacting the first conduction type buffer layer and the second conduction type ohmic contact layer, respectively, through the contact holes.~~

12. (Withdrawn - Currently Amended) The method according to claim 11, wherein ~~the forming an ion injection layer further comprises the ions injected into the central portion comprises ion injecting impurities such as beryllium (Be) or magnesium (Mg) ions, into the field controlling layer; and wherein the method further comprises heating the substrate. activating the injected ions by treating the substrate with a heating process.~~

13. (Withdrawn - Currently Amended) The method according to claim 12, wherein the substrate is heated ~~heating process is carried out at a temperature from in the range of 600 to 700 degrees Celsius (°C).~~

14. (Withdrawn) The method according to claim 11, further comprising carrying out a lapping process and a polishing process, so as to reduce a thickness of the photodiode.

15. (Withdrawn) The method according to claim 11, further comprising forming an anti-reflection layer on a lower surface of the substrate.

16. (Withdrawn - Currently Amended) The method according to claim 11, wherein at least one of the first conduction type buffer layer, the second conduction type field controlling layer, and the second conduction type buffer layer comprises ~~are formed of an InP semiconductor layer, and wherein the second conduction type light-absorbing layer comprises and the second conduction type ohmic contact layer are formed of an InGaAs semiconductor layer.~~

17. (Withdrawn - Currently Amended) The method according to claim 11, wherein providing the first conductive type buffer layer comprises ~~is formed by depositing an the InP semiconductor layer and an InAlAs semiconductor layer, and the InAlAs semiconductor layer is removed when forming the mesa structure.~~

Appl. No. : 10/802,593
Filed : March 17, 2004

18. (Withdrawn - Currently Amended) The method according to claim 11, wherein a total charge density of the central portion ~~the second conduction type ion injection layer and the second conduction type field controlling layer~~ is less than or equal to $3 \times 10^{12}/\text{cm}^2 \pm 20\%$, and a charge density of the peripheral portion ~~an edge region, where the ion injection layer is not formed,~~ is $2 \times 10^{12}/\text{cm}^2 \pm 20\%$.

19. (Withdrawn - Currently Amended) The method according to claim 11, wherein the amplifying layer ~~having the superlattice structure is either formed of~~ comprises at least one of the InAlAs semiconductor layer and an InAlGaAs semiconductor layer, or formed of the InAlAs semiconductor layer and the InAlGaAs semiconductor layer alternately deposited on each other.

20. (Canceled)

21. (Canceled)

22. (Canceled)

23. (Canceled)

24. (Canceled)

25. (Canceled)

26. (New) A photodiode, comprising:

a substrate;

a first conduction type buffer layer over the substrate;

an amplifying layer over the first conduction type buffer layer;

a second conduction type field controlling layer over the amplifying layer, the second conduction type field controlling layer comprising a central region and an edge region, the second conduction type field controlling layer comprising beryllium (Be) or magnesium (Mg) impurities in the central portion, not in the edge region;

a second conduction type light-absorbing layer over the field controlling layer;

a second conduction type buffer layer over the light-absorbing layer;

a first electrode electrically contacting the first conduction type buffer layer; and

a second electrode electrically contacting the second conduction type buffer layer.

27. (New) The photodiode according to claim 26, further comprising a second conduction type ohmic contact layer formed between the second conduction type buffer layer and the second electrode.

Appl. No. : 10/802,593
Filed : March 17, 2004

28. (New) The photodiode according to claim 27, further comprising a passivation layer covering a surface of the second conduction type ohmic contact layer and a surface of the first conduction type buffer layer.

29. (New) The photodiode according to claim 26, further comprising an anti-reflection layer on a surface of the substrate, the surface facing away from the first conduction type buffer layer.

30. (New) The photodiode according to claim 26, wherein the second electrode comprises an annular shaped body.

31. (Withdrawn - New) The method according to Claim 11, further comprising providing a second conduction type ohmic contact layer over the second conduction type buffer layer.

32. (Withdrawn - New) The method according to Claim 11, wherein injecting ions into the central portion is conducted prior to providing the light-absorbing layer.

33. (Withdrawn - New) The method according to Claim 11, wherein injecting ions into the central portion is conducted subsequent to providing the second conduction type buffer layer.

34. (Withdrawn - New) The method according to Claim 31, wherein injecting ions into the central portion is conducted subsequent to providing the second conduction type ohmic contact layer.